Eur J Vasc Endovasc Surg **17**, 458–462 (1999)
Article No. ejvs.1998.0765

Correspondence

Intra-arterial Pressure Measurements

Sir,

We agree the need to clarify the most reproducible, accurate and reliable methodology if intra-arterial pressure measurements and gradients (IAPM/G) are to be used for clinical decision-making. However, we would like to make certain comments on this subject and raise some questions regarding the paper by Robertson *et al*.

It has been known since 1963[2,3] that, at normal flow rates, resting pressure gradients occur only when stenoses cause reduction luminal cross-sectional area by more than 75–80% but that at higher flow rates stenoses of lesser area reduction will produce IAPG. The latter are termed "sub-critical" stenoses and it is these that are poorly assessed by imaging modalities, and which IAPM hyperaemic tests aim to detect. We were surprised that no mention was made of the work of Professor D. F. Young *et al*., who performed much experimental work on stenosis haemodynamics using model stenoses similar to those in this study, complemented by pursuing theoretical fluid dynamics, in the 1970s.[4–7] The variation of distal intra-arterial pressure with distance from the stenosis was known at that time, and Young showed that this pressure variation occurred for a distance up to five times the normal vessel lumen diameter from the narrowest point of the stenosis.[6] This is applicable generally to vessels of other dimensions, and is due to the phenomena of flow separation from the vessel wall. Young showed that there are many factors affecting the pressure gradient across a stenosis, not just cross-sectional area reduction and flow, as stenosis length and geometry/eccentricity[7] are also important.

The results presented are as predicted by basic considerations of stenosis fluid dynamics and add to our knowledge of inter-catheter variations in pressure readings. Regarding experiment 2, confirmation that pressure readings from catheters at the same point are the same whether facing antegrade or retrograde to the flow is in itself reassuring, and potentially has great clinical relevance, but little data was presented. Were multiple measurements made at 1 cm intervals, or at what point in the model was the pressure measured? If the latter, presumably measurements were at a site where flow was in a steady state, i.e. not within the region of variability 2 cm distal to the stenosis. If this site was distal to the stenosis the results are important, as they establish that antegrade measurement of distal pressure is reliable *in vitro* and thus the scope for the clinical use of these measurements is greatly extended. However, the influence of the antegrade catheter (facing downstream across the stenosis) on the absolute distal pressure being measured is not accounted for in this experiment; both catheters measure the affected absolute pressure at their tip, rather than reveal any pressure changes which occur due to the different methods of measurement. The results of experiment 4 do reveal this catheter-related effect with retrograde proximal measurements and thus infer that similar caution should be applied interpreting antegrade distal measurements, and this has been confirmed clinically in the coronary circulation.[8] The inaccuracies of the pullback method were observed clinically in 1985.[9] We assume that the guidewires were removed from the catheters to enable endhole and sidehole pressure measurements and, if so, would point out that a monorail catheter system enables the wire to remain across the lesion, whilst pressure measurements can be made at any position along the wire. Thus, pullback measurements are possible after PTA without the additional risk of recrossing the lesion, but are subject to the inaccuracies mentioned and any effect that the wire may also have. The Dutch iliac stent trial[10] employed the use of a 5F double-sensor catheter with proximal and distal electronic sensors 10 cm apart, enabling simultaneous measurements which have been shown to be reproducible.[11] However, again the catheter lies across the stenosis, and also the vasodilator used to produce hyperaemia was inconsistent (40 mg Tolazoline, 25 mg Papaverine or 100 μg Nitroglycerine), which may add a further variable.

From our personal clinical experience to date, and from the published literature, we agree that simultaneous proximal and distal pressure measurements are essential, and the bilateral access methodology is

1078–5884/99/050458+05 $12.00/0

the ideal, avoiding any confounding interaction with the stenosis. Distal measurements should be no nearer than five vessel diameters from the stenosis. Despite the author's conclusions, we would suggest that ideally both pressure measurements should be made using physically characterised, identical pressure catheter and transducer systems where possible to avoid any possible variability and provide inter-person standardisation for all measurements. Any hyperaemic manoeuvre performed clinically should have been shown to be reproducible, repeatable and safe; we use papaverine 20 mg which meets these criteria.[12] It is not uncommon to find that a residual pressure gradient persists after treating the obvious stenosis, and the catheter pullback technique performed whilst screening the catheter position is very useful for anatomically localising the point at which the physiological pressure drop occurs. We find this extremely useful for localising multiple stenoses, and sites requiring additional dilatation after the initial PTA or stenting procedure.

M. Tomlinson, F. Mitchell, A.-M. Belli, T. M. Buckenham, T. M. Loosemore and J. A. Dormandy
London, U.K.

References

1 Williams RG, Robertson I, Smye SW, Wijesinghe L, Kessel D. Sources of error in intra-arterial pressure measurements across a stenosis. *Eur J Vasc Endovasc Surg* 1998; **15**: 535–540.
2 May AG, DeWeese JA, Rob CG. Haemodynamic effects of arterial stenosis. *Surgery* 1963; **53**: 513–522.
3 May AG, Van de Berg L, DeWeese JA, Rob CG. Critical arterial stenosis. *Surgery* 1963; **54**: 250–259.
4 Young DF, Tsai FY. Flow characteristics in models of arterial stenoses – I. Steady Flow. *J Biomechanics* 1973; **6**: 395–410.
5 Young DF, Tsai FY. Flow characteristics in models of arterial stenoses – II. Unsteady Flow. *J Biomechanics* 1973; **6**: 547–559.
6 Young DF. Fluid mechanics of arterial stenoses. *J Biomechanical Engineering* 1979; **101**: 157–175.
7 Seeley BD, Young DF. Effect of geometry on pressure losses across models of arterial stenosis. *J Biomechanics* 1976; **9**: 439–448.
8 Anderson HV, Roubin GS, Leimgruber PP *et al.* Measurement of transstenotic pressure gradient during percutaneous transluminal coronary angioplasty. *Circulation* 1986; **73**(6): 1223–1230.
9 Baker AR, Evans DH, Taylor JD, James DC, Bell PRF. The accuracy of "pull-through" pressure measurements and papaverine testing. *Angiology* 1985;
10 Tetteroo E, Haaring C, van der Graaf Y, van Schaik JPJ, van Engelen AD, Mali WPTHM, for The Dutch Iliac Stent Trial Study Group. Intraarterial Pressure Gradients after Angioplasty or Stenting of Iliac Artery Lesions. *CVIR* 1996; **19**: 411–417.
11 Tetteroo E, Haaring C, Van Engelen AD, Van der Graaf Y, Masli WPTHM. Therapeutic consequences of variation in intraarterial pressure measurements after iliac angioplasty. *CVIR* 1997; **20**(6): 426–430.
12 Quin RO, Evans DH, Bell PRF. Haemodynamic assessment of the aorto-iliac segment. *J CVS Surgery* 1975; **16**: 586–589.

Authors' reply

We thank Mr Tomlinson and his colleagues for their interest in our paper. We are familiar with the work of Professor Young and happily acknowledge the importance of his contribution to the understanding of stenosis haemodynamics. We focused our discussion and references on sources of error in pressure measurements and within a short report it was not possible to include all of the original work.

In experiment 2, measurements were taken at 5 and 10 cm downstream from each of the three stenoses using each of the three catheters and at 300, 600 and 900 ml/min. The antegrade catheter was through the stenoses when each of the pressures was recorded. We chose to use conventional "over the wire" angiographic catheters for all experiments to make the study as clinically relevant as possible. Monorail catheters are rarely used outside the coronary circulation; however, the use of an 0.018'' wire through a conventional 4F catheter with a Touhy–Borst side-arm adaptor will allow measurements at any point along the length of the wire. We must reiterate that simultaneous proximal and distal pressure measurements, preferably with bilateral access, are the ideal.

We read with interest the comments regarding reproducible hyperaemic manoeuvres. We are not convinced that any physiological manoeuvre is consistent in all patients and have particular concerns regarding the measurement of flow across stenoses prior to more distal grafting. In many patients, the outflow is very diseased and further vasodilatation may not be possible. In such patients, flow is reduced and a pressure gradient is not demonstrated. After grafting the change in outflow increases flow across the lesion and a pressure gradient is revealed. Therefore, we consider each patient individually and do not rely on any single manoeuvre.

I. Robertson, R. G. McWilliams, D. Kessel and S. Smye
Leeds, U.K.

Sclerotherapy

Sir,

Mr Galland *et al.*[1] have produced an interesting survey on the current use of sclerotherapy for varicose veins in Britain and Ireland. A survey on varicose vein practice as a whole by the Audit Committee of the Vascular Surgical Society of Great Britain and Ireland was performed last year.[2] This did not go into the detail which Mr Galland and his colleagues have done regarding schlerotherapy; however, it may be interesting to compare the results of these two surveys relating to sclerotherapy. The Audit Committee survey was also distributed to all members of the Vascular Surgical Society. There were 278 replies out of 427 (response rate of 65%). Twenty per cent of respondents saw varicose veins in a dedicated venous clinic and 18% had a sclerotherapy clinic. On the National Health Service, 68% surgeons performed sclerotherapy for varicose veins and 27% for thread veins. In private practice these figures were 62% and 49%, respectively.

Regarding the indications for sclerotherapy, the wording of the Vascular Surgical Society audit was slightly different to that in Mr Galland's audit. 1.1% of respondents were using sclerotherapy as an alternative to surgery in the presence of long saphenous vein or short saphenous vein reflux (this would seem to correspond to the primary with proximal incompetence group, which totalled 4.6% in Mr Galland's study). 14% of respondents used sclerotherapy as an alternative to surgical avulsions, having performed saphenofemoral or saphenopopliteal disconnection, and 60% performed sclerotherapy for missed varicose veins following surgery (77% in Mr Galland's study). Regarding the practitioner performing the sclerotherapy, in the VSS study this was a consultant in 65% of cases, and a surgical trainee in 33% of cases (41% and 45% in Mr Galland's study).

These studies show an interesting variation in studies on the same group of surgeons. This may to some extent reflect the wording of the questions asked, but also demonstrates the difficulty in performing these studies and their limitations.

T. A. Lees
Newcastle, U.K.

References

1 Galland RB, Magee TR, Lewis MH. A survey of current attitudes of British and Irish vascular surgeons to venous sclerotherapy. *Eur J Vasc Endovasc Surg* 1998; **16**: 43–46.
2 Lees TA, Ridler B, Szymanska TH. A survey of the current management of varicose veins by members of the Vascular Surgical Society. Submitted to *Annals of the Royal College of Surgeons of England*, 1998. (Submitted).

Graft surveillance

Sir,

I would like to comment on the recently published paper "The Utility of Duplex Scanning in Infrainguinal Vein Graft Surveillance: Results from a Randomized Controlled Study" by Ihlberg *et al.*[1] The authors state that vein graft surveillance based on duplex scanning does not lead to a higher patency compared to conventional surveillance. The conclusion is probably correct based on their data, but I think the study has a number of drawbacks. There were 23 different examiners out of which seven were trainees. I believe that there is consensus that duplex is an excellent method in the hands of an experienced examiner but also that it is an operator-dependent method and that there is a long learning curve when vein grafts are to be examined. The authors state that patient compliance was good but only 60% of all planned duplex examinations were actually carried out. A 40% loss of examinations could lead to a number of graft occlusions in the interval between two examinations. There were also a large number of examiners involved in the evaluation of the surveillance data. Our experience is that only a very limited number of examiners should be involved, especially during the build-up phase of a surveillance programme.

In our previously published study only a few vascular technicians did the duplex scanning and the results from each examination was seen by one vascular surgeon and one vascular physiologist. The failing grafts in our study were identified by a combination of duplex and ABI measurements, but never with an ABI measurement alone. The two failing vein grafts in the control group were actually identified by duplex![1] In the present study the patients were randomised at the time of surgery, but occluded grafts at the one month control were excluded from analysis. I believe that these patients should not have been excluded. There are a number of reasons for graft occlusions during the first 30 days including technical errors. At our institution 38 out of 318 (13%) femoropopliteo/crural bypasses performed from 1 January 1994 to 10 August 1998 occluded during the first postoperative month. All our patients are entered into a surveillance programme based on duplex and the first examination is made one or two days after surgery. Our experience is that an early postoperative duplex

scan is very valuable. Technical defects can be identified and corrected, and failing grafts subjected to more intense surveillance.

I do, however, agree with the authors on one of their conclusions. There is a need for a large randomised study evaluating the effect of vein graft surveillance with duplex on patency and, in particular, limb salvage.

A. Lundell
Malmo, Sweden

References

1 Ihlberg L, *et al.* The utility of duplex scanning in infrainguinal vein graft surveillance: results from a randomised controlled study. *Eur J Vasc Endovasc Surg* 1998; **16**: 19–27.
2 Lundell A, Lindblad B, Bergqvist D, Hansen F. Femoropopliteo-crural graft patency is improved by an intensive surveillance program: a prospective randomized study. *J Vasc Surg* 1995; **21**: 26–34.

Authors' reply

We thank Dr Lundell for his interest and valuable comments on our article. We do agree that the quality of a surveillance programme is enhanced if only a few experienced operators are used, but one of the main objectives of our study was to see how surveillance succeeds as a part of routine clinical work. If surveillance is to be recommended for wide clinical use it should be effective also as a part of daily routine of an academic referral centre. Dr Lundell was worried about the quality of our duplex scanning. However, as the scans were not double-checked or controlled with angiograms, any assumptions made on the quality based merely on the number of examiners involved are just educated guesses. We are not aware of any consensus of quality-demands on the duplex examiner and to our knowledge the length of a learning curve has not been studied. Then again, if duplex scanning for vein grafts is susceptible for large inter-observer variations and extraordinary skills are needed, one can question whether it fulfils the criteria of a good screening method.

We feel that it is not the quality of duplex which is the problem. The revision rate in the duplex group was 2.75 times more than that in the ABI group (11 vs. 4), which is in line with documented accuracy figures of duplex and pressure measurements in the case of finding haemodynamically significant stenoses. The problem seems to be that the treatments performed on the basis of surveillance were not successful. Others have also published their experiences of low efficacy of prophylactic graft revisions,[1] and questioned the currently accepted intervention criteria.

One aim of our trial was to show pitfalls which are unique to surveillance studies, which Dr Lundell has also noticed. The ability to follow up all patients is very difficult, and is 100% attendance a realistic expectation for our morbid patient group of advanced age? We think not. Our study does not give the answer as to whether some graft occlusions could have been avoided with stricter adherence to the study protocol. Therefore, after this pilot study we analysed our whole surveillance trial material from January 1991 to December 1995 for subset of patients who had completely accomplished follow-up, but disappointingly no positive outcome with duplex could be demonstrated.[2]

We also share his opinion that one month's cut-off point between failures caused by technical reasons and neointimal hyperplasia is artificial and overlapping does occur. The one-month occlusion rate in this study was 17% for the ABI group and 20% for the duplex group and does not explain the poorer outcome for the duplex group. We congratulate Lundell's group for low one-month failure rate, but can they demonstate that the improvement is only due to use of predischarge duplex? Furthermore, no evidence exists that with any intraoperative and pre-discharge method one can define risk groups for more intensive surveillance.[3,4] The one-year cumulative patency and limb salvage rates are presented with the first-month failures included, but they are excluded when analysing the impact of surveillance on results.

The principal difference between our study and that of Dr Lundell's group is that in their study, the net effect of the surveillance programme was examined over the non-surveillance group. Our study was designed only to allow direct comparison between surveillance methods. Neither of these studies can be used as a strong argument for or against the benefits of a surveillance programme, due to a small sample size and the risk of a type II statistical error. A considerable improvement in limb salvage rates needs to be shown in order to justify surveillance. This seems to be a hard task, even with a large-scale randomised study.

L. Ihlberg, M. Luther and M. Lepäntalo
Helsinki, Finland

References

1 Dougherty MJ, Calligaro KD, DeLaurentis DA. Revision of failing lower extremity bypass grafts. *Am J Surg* 1998; **176**: 126–30.

2 Ihlberg L, Luther M, Albäck A, Kantonen I, Lepäntalo M. Does a completely accomplished duplex-based surveillance reverse vein graft failure? (Submitted for publication. Presented in ESVS XII Annual Meeting October 1998, Paris, see Abstract Book p. 112).
3 Tong Y, Royle J. Should peri-operative infra-inguinal graft duplex scans be routinely performed? *Aust NZ J Surg* 1998; **68**: 251–4.
4 Olojugba DH, Varty K, Hartsthorne T, Naylor AR, Bell PR and London NJ. Predischarge duplex imaging of infrainguinal vein grafts does not predict the development of stenoses. *Br J Surg* 1998; **85**: 1225–7.